Ensuring a Safe Technological Revolution

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In an era of increasing global hostilities, the Department of Defense (DoD) faces increasing fiscal constraints. Maritime security challenges continue while the defense industrial base shrinks, platforms and systems age and readiness declines. To help confront these challenges and meet the needs of defense missions, new enabling technologies must be identified and integrated into the DoD.

Additive manufacturing (AM), commonly referred to as 3D printing, is an identified enabling technology with the potential to radically change how the DoD, the Department of the Navy, and their partners and allies develop, manufacture and support their platforms and systems. In the last decade, AM technology has moved beyond

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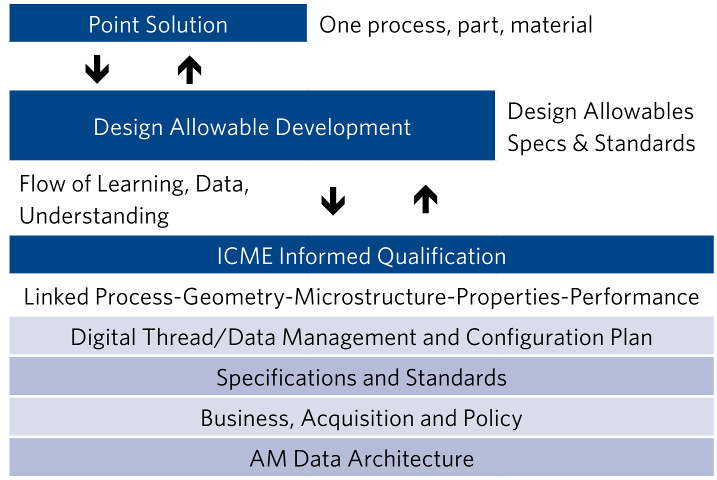
simple plastic prototypes to printing metal, integrated circuits, biomaterials and compound materials. Reports of AM's technology advancement can seem to approach the realm of science fiction, with demonstrations of 3D printing of various body parts such as customized bone and joint implants.

The naval community has successfully used AM technology in its facilities since the early 1990s. Polymer AM systems have become commonplace in enabling unique production tooling, rapid prototyping, training aids and customized repair part development. The flexibility and digital aspects of AM, which enable parts to rapidly move through design iterations, have opened additional options in production tooling that would be costly and time-consuming to set up through traditional manufacturing. The types of parts producible by AM increase every day. AM systems that "print" metals are maturing to the point where direct manufacture of certain safety critical parts is on the horizon.

Figure 1. Navy Approach to Qualification/ Certification



AM creates opportunities that range from designing parts for increased capabilities and reliability to re-imagining naval logistics and supply chains. A digital supply chain can enable "stock[ing] the data, not the part" and fabricating parts when and where they are needed. This supply chain resiliency, coupled with manufacturing agility for increased innovation and performance capabilities, is the cusp of the AM technology revolution.

AM provides the opportunity to truly reduce costs, minimize obsolescence issues and improve both capability and readiness across the entire life cycle of naval systems—including both the new developments and systems of today. But it will require a common vision across the DoD and industry to address not only AM's technical challenges but include the policy, business and acquisition changes necessary to realize its potential.

Barriers to AM Implementation

Qualification/Certification: The ability to qualify and certify AM parts, including safety-critical metallic parts is a fundamental barrier to its more extensive use in Navy platforms. Safety-critical parts are "head hurters"—difficult to produce, made only of well understood and characterized materials, with very specific manufacturing processes and rigorous testing requirements. A "qualified" process is capable of consistently turning out a product that has acceptable properties. A "certified" part can perform properly in its operating environment. The conventional qualification/certification building block approach used today requires that a single process be standardized and characterized and that statistically substantiated data be generated. Significant cost and time are associated with this conventional process. Given the large number of AM processes, vendors, equipment models and potential material options, the Navy is examining methods to enable rapid qualification over the long term as the traditional qualification certification process will make it impossible to achieve the flexibility that AM offers. To enable the innovative designs, customization and improved performance promised by AM, qualification and certification process must be accelerated by an order of magnitude.

The naval community has adopted a three-pronged approach to overcoming the Barriers to Qualification/Certification (see Figure 1). Because of the complexity of the AM processes, the long-term strategic approach is to use Integrated Computational Material Engineering (ICME) to inform qualification and certification. ICME links the AM process, part geometry, material microstructure and properties together to understand these relationships for end use. In the near term, the traditional approach to qualification and certification is being utilized on a case-by-case basis. These point solutions are parts demonstrations that help accelerate AM qualification by generating sufficient engineering confidence to field critical demonstration parts. The understanding and knowledge gained through multiple demonstrations and case-by-case certifications allow us to design parts that are optimized for AM production and begin to define the necessary naval requirements for AM specifications and standards.

The data gathered from demonstrations support our goal of an "ICME informed" approach to qualification. When implemented, ICME-informed qualification will reduce the required testing and facilitate the building of parts using different AM processes, manufacturers and equipment. The naval plan's final step links the ICME models that allow selection of the right AM process, materials and component design to a suite of sensors and controls for monitoring the AM manufacturing process. This provides real-time understanding of any manufacturing issues that will affect quality and inspection and that can significantly reduce testing requirements—depending on the part's criticality and operating environment.

Another critical aspect of qualification and certification is nondestructive inspection (NDI). Basic work is still needed on identifying anomalies in AM processes and materials, the relationship of these anomalies to processing parameters and their effects on part performance. The material variability that is observed and must be understood through modeling and simulation also poses challenges to NDI. Specific issues include variable microstructures, complex geometries and adaptation of existing and new inspection methods for AM.

Polymer and composite AM materials for use in naval applications also require qualification and certification. A current hurdle to usage of polymeric materials aboard ship is the inability of currently tested AM polymer materials to comply with standards regarding flammability, smoke or emissions and toxicity. Polymeric AM materials have been used in nonstructural aviation applications.

The vision of parts on demand, made available when and where they are needed, will be achieved by lowering the cost and enhancing the operational availability of naval weapon systems. The Navy is actively engaging its various communities to align needs and ensure that AM can be safely accelerated and used to meet critical needs.

The Data Problem: AM is a digital process, from design through printing. The digital process depends on a significant quantity of data. The amount, type and methodology for managing the data associated with an AM part are readily amenable to existing government methods for managing technical data. While the DoD as a whole is beginning to move toward digital 3D data for new systems, addressing obsolescence and repair issues for legacy platforms and systems that use standard two-dimensional drawings requires significant analysis and reverse engineering to enable adaptation for AM. This data migration has occurred in defense prime contractors and major suppliers that have gone digital in their design and production infrastructures. These suppliers have migrated to a 3D model based environment that uses product life-cycle management software to ensure every element of a product is managed—from design work done in computer-aided design, to analysis, qualification/certification, computer-aided manufacturing, configuration management and supply. The infrastructure and tools needed to support the digital technical data required for AM are the standard in defense industry and commercial manufacturing companies. The Navy will need to implement the same infrastructure and standards to make AM achievable.

Business, Acquisition and Policy: It is difficult to develop an AM use cost model that captures the associated savings and cost avoidance. This is particularly true in defense, where most cost models are based on actual cost history for similar programs.

Because it is a technology in which shorter production runs for complex parts can actually prove more cost-effective than long production runs, AM presents a unique costing challenge. While material and design costs are higher for AM parts production, the specialized tooling costs and "touch labor" costs are much lower, and the performance gained can dramatically reduce life-cycle costs. Validated cost data are scarce, and accurate AM cost models need to be assigned a high priority.

Contracting with AM in mind (buying adequate data rights, enabling a wider supply base, and moving toward shorter acquisition cycles) will require a different approach to acquisition planning. While only a limited number of suppliers can produce an airplane, the entrance cost to AM is significantly lower, and over the next decade there will be many suppliers that can make safety-critical parts. In that future, defense policy may be the biggest impediment to broad adoption of AM. Specialty metals restrictions for defense contracts may limit options in expanding our industrial base for complex parts, and impact the level of cost sharing we achieve with our NATO partners.

Accelerating AM for Defense

How do we leverage the huge AM investments by commercial industry, while ensuring that AM can safely be used for carrier aviation and on our nuclear submarines? If we want AM to mature for defense applications, and if we ever want to use it in the future, we need to start now.

Every platform or system in the naval inventory includes parts that are hard to get. These parts are difficult to produce and are made with materials that require long lead times. They have limited supply bases and suboptimal designs; the DoD has hundreds of thousands of "problem children" parts. The ability to produce a subset of these parts through AM will dramatically increase readiness and reduce costs. And—if we commit to making them through AM—we can mature AM qualification and certification, AM data management and AM business processes much more quickly.

There are other steps that we need to take in order to accelerate AM use:

- Increase collaboration opportunities across the AM community.
- Develop an AM data architecture that will allow us to tie all the AM data together across the defense enterprise.
- Work with our suppliers, the Defense Logistics Agency, and the Naval Supply Systems Command to source AM parts.
- Validate DoD cost models and manage the data rights for maximum reuse.

If we want to use AM, we need to start using AM. And there's no time like the present.

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